

**WE CLAIM:**

1. In spool valve apparatus having a plurality of respective valves operated sequentially by the rotation of a drive shaft, each spool valve comprising (a) a cylinder having at least a first port  
 5 defining a first fluid passage, and (b) a spool having a stem portion and at least one port-blocking portion, said spool being movable axially within the cylinder between first and second positions so that, when said spool is in said first position, said fluids are permitted to move past said stem portion and through said first  
 10 fluid passage and, when said spool is in said second position, said first fluid passage is blocked, the improvement comprising:

- a cam track rotated by said drive shaft and having at least two parallel surfaces; and

- a plurality of cam followers, each cam follower being  
 15 associated with, and aligned in a predetermined position relative to, a respective one of said spools, and each cam follower being captured between said parallel surfaces of said cam track for relative moving engagement therewith for controlling said axial motion of each respective spool and said sequential operation of said  
 20 respective spool valves in response to the rotation of said drive shaft;

and wherein:

a 25 - said stem portion of each respective spool defines a passageway formed by one of (a) no sidewalls with a central support comprising a non-cylindrical curved surface shaped *hydrodynamically*, and (b) a pair of sidewalls with said passageway formed therebetween, said central support and said sidewalls being positioned in a predetermined orientation relative to said respective first fluid port of said cylinder to facilitate the flow of fluids past  
 30 said stem portion and through said first fluid port when said stem portion is aligned therewith.

2. The spool valve improvement of claim 1 wherein:

- said cylinder comprises a second port spaced from said first port and defining a second fluid passage; and

5 - when said spool is in said first position and said fluids are permitted to move past said stem portion and through said first port, said second fluid port is blocked;

- when said spool is in said second position, said first fluid passage is blocked and fluids are permitted to move past said stem and through said second fluid port; and

10 said predetermined orientation of said central support and of said passageway between said sidewalls of said stem portion is positioned to facilitate the flow of fluids (a) past said stem portion and through said first fluid passage when said stem portion is aligned with said first fluid port and (b) past said stem portion and  
15 through said second fluid passage when said stem portion is aligned with said second fluid port.

20 3. The spool valve improvement of claim 2 wherein said pair of sidewalls of said stem portion has interior surfaces that form said passageway therebetween, and each said interior surface is shaped <sup>hydrodynamically</sup> ~~aerodynamically~~ to facilitate the flow of fluids through said stem portion and to direct the flow of fluids to and from said respective first and second fluid ports when said stem portion is aligned therewith.

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4. The spool valve improvement of claim 2 wherein said stem portion having a pair of sidewalls further comprises a pair of passageways formed between said sidewalls, each said passageway being oriented to direct fluid to and from a respective one of said  
30 cylinder ports when said stem portion is aligned therewith.

5. The spool valve improvement of claim 2 wherein said non-cylindrical central support forms a pair of passageways, each said passageway being oriented to direct fluid to and from a respective one of said cylinder ports when said stem portion is aligned therewith.

- 7 7 ~~6~~. The spool valve improvement of claim 1 wherein said predetermined position of each said cam follower relative to its respective spool prevents rotation of each spool about the axis of its respective cylinder when said roller is in rolling engagement with said cam track and, thereby, maintains said predetermined orientation of said central support and said sidewalls of said stem portion to facilitate said fluid flow.

- 8 ~~7~~ <sup>77</sup>. The spool valve improvement of claim ~~6~~ wherein each said cam follower comprises a roller captured for rolling engagement with said cam track.

- 9 9 ~~8~~ <sup>88</sup>. The spool valve improvement of claim ~~7~~ wherein each said spool has a tang through which said respective roller is received and supported in said predetermined position to permit said rolling engagement with said parallel surfaces of said cam track.

- 10 ~~9~~ <sup>88</sup>. The spool valve improvement of claim ~~7~~ wherein said parallel surfaces of said cam track are divided into two aligned mirror-image portions, and wherein each said roller is in rolling engagement with both said aligned mirror-image portions at all times.

6 10. The spool valve improvement of claim 2 wherein said plurality of cylinders is positioned equidistant from each other along axes extending radially from a central axis.

5 11. The spool valve improvement of claim 1 wherein each said sidewall of said stem portion has an exterior surface and further comprises a pressure-balancing channel formed therein.

Sub 135 10 12. A spool for a valve for controlling the flow of fluids, said valve having a body including a cavity for receiving said spool, said cavity having an axis and at least one port defining a first fluid passage, and said spool comprising:

- a first port-blocking portion and a stem;  
- said spool being movable axially within said cavity between  
15 first and second positions so that, when said spool is in said first position, said first fluid passage is blocked by said first port-blocking portion, and, when said spool is in said second position, fluids are permitted to move past said stem and through said first fluid passage; and

a 20 - said stem of each respective spool defining a stem passageway formed by one of (a) no sidewalls with a central support comprising a non-cylindrical curved surface shaped hydrodynamically, and (b) a pair of sidewalls with said stem passageway formed therebetween, said central support and said sidewalls being  
a 25 positioned relative to said respective first fluid port of said cylinder to permit the flow of fluids through said stem passageway and through said first fluid port when said stem portion is aligned therewith.

13. The spool of claim 12 further comprising an orientation mechanism for positioning said stem passageway formed by said sidewalls and by said central support in a predetermined orientation relative to said first fluid passage so that said fluid flow through  
5 said first port is facilitated at all times when said stem is aligned therewith.

14. The spool according to claim 13 wherein said spool valve for controlling the flow of fluids is incorporated in a machine having  
10 a control cam surface rotated by a drive shaft, said control cam having at least two parallel surfaces, and wherein:

- said orientation mechanism comprises a cam follower aligned in a predetermined position relative to said spool, said cam follower being captured between said parallel surfaces of said  
15 control cam for relative moving engagement therewith for controlling axial motion of said spool.

15. The spool according to claim 14 wherein said cam follower is a roller.

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16. The spool according to claim 12 wherein each said sidewall of said stem portion has an exterior surface and further comprises a pressure-balancing channel formed therein.

25 17. The spool according to claim 12 wherein said cavity in said valve body includes a further port defining a second fluid passage, and said spool further comprises:

- a second port-blocking portion separated from said first port-blocking portion by said stem and, when said spool is in said first position, said first port-blocking portion of said spool blocks said first fluid passage while fluids are permitted to move through said stem passageway and through said second fluid passage, and when said spool is in said second position, said second port-blocking portion of said spool blocks said second fluid passage while fluids are permitted to move through said stem passageway and through said first fluid passage; and
- an orientation mechanism for positioning said stem passageway in a predetermined orientation relative to both said first fluid passage and said second fluid passage so that fluid flow through said stem passageway is facilitated at all times when said stem is aligned, respectively, with said first and second fluid passages.

18. The spool according to claim 17 wherein said pair of sidewalls has interior surfaces that form said stem passageway therebetween, and each said interior surface is shaped ~~aerodynamically~~ <sup>hydrodynamically</sup> to facilitate the flow of fluids through said stem passageway and to direct the flow of fluids to and from said respective first and second fluid ports when said stem portion is aligned therewith.